Development of Novel Materials for High-Performance Energy Storage Devices

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By

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CERTIFICATE OF AUTHORSHIP

I, Xiao Tang, certify that the work presented in this thesis has not previously been submitted for a degree nor as a part for a degree.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Xiao Tang

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DEDICATION

To my beloved family. Thank you for giving a different meaning of life to me.

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RESEARCH PUBLICATIONS

1. Xiao Tang, Dong Zhou*, Peng Li, Xin Guo, Bing Sun, Hao Liu, Kang Yan, Yury Gogotsi*, Guoxiu Wang*. MXene-based dendrite-free potassium metal batteries. **Adv. Mater.** 2020, 32 (4), 1906739.

2. Xiao Tang, Dong Zhou, Peng Li, Xin Guo, Chengyin Wang, Feiyu Kang, Baohua Li*, Guoxiu Wang*. High-performance quasi-solid-state MXene-based Li-I batteries. **ACS Cent. Sci.** 2019, 5 (2), 365-373.

3. Xiao Tang, Xin Guo, Wenjian Wu, Guoxiu Wang*. 2D metal carbides and nitrides (MXenes) as high-performance electrode materials for lithium-based batteries. **Adv. Energy Mater.** 2018, 8 (33), 1801897.

4. Weizhai Bao, Xiao Tang, Xin Guo, Sinho Choi, Chengyin Wang, Yury Gogotsi*, Guoxiu Wang*. Porous cryo-dried MXene for efficient capacitive deionization. **Joule** 2018, 2 (4), 778-787.

5. Dong Zhou, Xiao Tang, Xin Guo, Peng Li, Devaraj Shanmukaraj, Hao Liu, Xiaochun Gao, Yizhou Wang, Teofilo Rojo, Michel Armand, Guoxiu Wang*. Polyolefin-based Janus separator for rechargeable sodium batteries. **Angew. Chem. Int. Ed.** 2020, DOI: 10.1002/anie.202007008.

6. Dong Zhou, Anastasia Tkacheva, Xiao Tang, Bing Sun, Devaraj Shanmukaraj, Peng Li, Fan Zhang, Michel Armand, Guoxiu Wang*. Stable conversion chemistry-based lithium metal batteries enabled by hierarchical multifunctional polymer electrolytes with near-single ion conduction. **Angew. Chem. Int. Ed.** 2019, 58 (18), 6001-6006.

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ABSTRACT

Recently, tremendous efforts have been devoted to the development of novel materials for advanced energy storage devices that simultaneously possess high energy density and power density. Two-dimensional (2D) materials have been considered to be promising in the field of large-scale energy storage. After the discovery of graphene, a large family of two-dimensional transition metal carbides/nitrides (MXenes), derived from MAX phase precursors, have attracted extensive attention owing to the superior physical and chemical properties, which includes excellent electrical conductivity, high mechanical strength, hydrophilic features, multiple possible surface functional groups, superior specific surface area, and the ability to accommodate intercalants. In this thesis, the preparation strategies, structures, properties, and applications of MXene materials in lithium-based and potassium-based batteries have been systematically reviewed. Moreover, we rationally design various MXene materials for lithium-iodine, potassium metal, and aqueous lithium-sulfur batteries. The usage of MXene materials can effectively enhance the electrochemical performances of these energy storage devices. This thesis may provide an insight into the development of two-dimensional MXene materials for large-scale energy storage.